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(54) ELECTROPHOTOGRAPHIC COPIER

(71) We, ITEK CORPORATION, a corporation organised and existing under the laws of the State of Delaware, United States of America, of 10 Maguire Road, Lexington, Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electrophotographic copier.

Many electrophotographic copiers are designed to carry out an electrostatic process wherein a conductive backing having a photoconductive insulating layer thereon is electrostatically imaged by first uniformly charging its surface and subsequently exposing the charged surface to a pattern of activating electromagnetic radiation such as light. The radiation pattern selectively dissipates electrostatic charges in illuminated areas on the photoconductive surface to produce a latent electrostatic image in non-illuminated areas. This latent electrostatic image can be developed to form a visible image by depositing developer materials thereon by a variety of development techniques, the most common of which is cascade development in which said developer is cascaded across the latent image. Solid developer materials are customarily two component systems containing finely divided pigmented particles commonly called "toner", and relatively coarser, larger beads commonly called "carrier beads". The developed toner image is transferred to a final substrate medium, such as plain paper, by electrostatic transfer, pressure contact, or otherwise. Once transferred, the tone image is fused or fixed to the final substrate medium, e.g. by heat, solvent vapor or a fixative coating.

It is desirable to have copiers as described above which produce copies rapidly, but high speed electrophotographic copiers heretofore available have had a number of features which it is desirable to improve. Usually, for example, high speed copiers are large, bulky machines which consume large amounts of power. Additionally, copy quality often suffers on such machines, particularly in features such as background. It is desirable to produce copies with minimum background levels, i.e. developer in non-image areas, but this has not been possible with most high speed machines.

The invention comprises an electrophotographic copier comprising a number of unique features which interrelate so that the copier is compact, produces high quality copies rapidly, and requires smaller amounts of power than is customary with high speed copiers. The invention provides an electrophotographic copier comprising:

a. a rotatable drum having a photoconductive, insulating surface thereon;

b. means to apply a uniform electrostatic charge pattern to the surface of said drum;

c. means to expose said uniform electrostatic charge pattern to a light image of an original thereby forming a latent electrostatic image of the original on the surface of said drum;

d. cascade developer means for cascading electroscopic developer over said latent electrostatic image, said cascade developer means including a member closely positioned to the surface of said photoconductive drum and defining a narrow development zone therebetween, said member having means associated therewith for partially converting the tangential momentum, with respect to the drum, of developer particles passing in use through said zone into radial momentum with respect to the drum;

e. an intermediate elastomeric transfer belt positioned to remove the developed toner image from the surface of said drum;

f. radiant energy emitting means for heating the toner image on said electrostatic transfer belt; and

g. means for bringing one or more substrate mediums into contact with heated toner image on said transfer belt whereby said image is transferred and fused to said substrate medium, which means is adapted to maintain contact between said transfer belt and said substrate medium after transfer

of the toner image to the substrate medium.

It is believed that the combination of a high efficiency development apparatus in which substantial radial velocity components are imparted to the developer, together with an elastomeric transfer belt, particularly one made of silicone rubbers, or fluoroelastomers, results in copies having exceptionally low background.

The drawing illustrates schematically an electrophotographic copying apparatus of this invention employing a modified cascade development system with a thermally efficient transfer, fusing and paper handling system.

Referring now to the drawing in more detail, a photoconductive drum 10 is shown which typically consists of a conductive metal substrate, 11, such as aluminium, coated on its outer surface with a layer of photoconductive insulating layer 12, typically vitreous selenium. Drum 10 rotates at its axis and is shown rotating in a counterclockwise or "downhill" direction.

A cleaning station 20 is provided to remove residual toner from the photoconductive drum 10 prior to the start of each imaging sequence. Cleaning station 20 includes a fur cleaning brush 21 mounted on slidable element 22 so that the brush can be disengaged.

A uniform electrostatic charge is formed on the surface of drum 10 by means of corona charging station 30. This station includes corona element 31 which is electrically connected to a power source such as battery 32 and to ground.

Uniformly charged drum 10 then passes imaging station 40. Light sources 41 illuminate original 42 which is imaged through imaging lens 43 and slit 44 to form an electrostatic latent image of the original on the surface of photoconductive drum 10. Scanning optics can also be used, but fixed optics are preferred to maintain compactness.

The copier illustrated in the drawing is a compact but high speed copier. Its size is kept relatively small by using a small diameter photoconductive drum. The drum might be, for example, nominally five inches in diameter, which is required to handle conventional originals such as $8\frac{1}{2} \times 11$ inch typed pages. Because the drum is small, it must be rotated at relatively high speeds to produce copies rapidly; typically this means that the drum must move at a speed of about 10 inches/second or more. Because of the shorter development zone and higher drum speed, highly efficient development systems are required. Cascade developers can be modified to provide such highly efficient development apparatuses, and one such modified cascade developer is illustrated in the drawing.

Cascade development apparatus 50 includes a housing 51 including within it a basket elevator system formed by an endless belt 52 having buckets 53 thereon. Electrostatic developer is lifted from a reservoir section 54 in buckets 53 to a point at the upper portion of drum 10 and then cascaded over the drum surface by means of feed guide 55. As developer cascades over drum 10, toner particles separate from the carrier beads and deposit on the drum surface in accordance with the latent electrostatic image thereon, thus forming a visible toner image. Spent developer is guided back into reservoir 54 by guide 56. The biased developement electrode 57 has a roughened surface which can be formed by knurling its surface or otherwise forming protuberances thereon. This roughened surface interferes with the normal flow of developer and is particularly effective at increasing the radial velocity of toner through the development zone to effect increased developer efficiency. For a more detailed description of this type of modified cascade development apparatus, see our co-pending British Patent Application 54777/74 (Serial No. 1,494,219.

Other high speed high efficiency development apparatuses could be used; the important parameter being development efficiency. Included, are such development systems as magnetic brushes, fur brushes, fluidized bed developers, cascade development apparatus modified by moving belts, uphill cascade developers. These systems are well known to those skilled in the art.

Transfer and fusing station 60 is designed to keep the copier compact, provide outstanding thermal efficiency thereby lowering the overall power requirements for the copier and to produce clean, low background copies. An intermediate transfer belt 61 is trained to pass in an endless loop around rollers 62, 63, 64, 65, 66 and 67. Belt 61 is driven by suitable means such as motor 68 which is connected to and drives roller 67 in a clockwise direction. Roller 62 can be adjusted by tensioning spring 69 to take up any slack created in intermediate transfer belt 61 caused by an dimensional changes due to variations in temperature or otherwise. Roller 62 is also preferably constructed of hard rubber which is electrically leaky so that any background electrical charges built up on belt 61, such as triboelectric charges built up between any of the rollers and the belt, will dissipate naturally before the belt contacts photoconductive drum 10.

Transfer is accomplished at T_1, i.e., the point at which belt 61 contacts photoconductive drum 10. Transfer is controlled by transfer roller 70 which is positioned at the back side of transfer belt 61 so that it can be moved in and out by adjusting tensioning spring 71.

Paper 72 is fed from paper roll 73 and brought into contact with the toner image on

belt 61 by guide rollers 74 and 75 acting in cooperation with belt rollers 65 and 66. The contact zone between belt and paper is deliberately designed to be elongated so that paper 72 absorbs heat from belt 61 and carries it out of the copier. The exact length of this elongated zone will depend on many factors such as the speed at which the paper and belt are moving, but in general should be sufficient to leave the belt and paper in contact for at least 0.5 seconds.

Heat is supplied in a selective manner to the toner image on belt 61 by radiant heater 80. Radiant heater 80 consists of two radiant heating lamps 81 surrounded by a heat shield 82 which is properly insulated and slidable shield 83. Slidable shield 83 can be positioned directly under lamps 81 when the copier is in a standby state so that lower amounts of power can be supplied to lamps 81 while still maintaining the chamber at a high temperature. When copying is initiated, slidable shield 83 is moved to the left in which position lamps 81 radiating heat to belt 61 so that copying can begin. Because the chamber is maintained at an elevated temperature in the standby mode, copying can begin immediately even though the lamps have not risen to full power.

Transfer and fusing station 60 is designed to provide the type of thermal efficiency required in high speed copying systems if large amounts of power are to be avoided. Intermediate transfer belt 61, for example, is fabricated from appropriate materials in relatively thin layers to provide the belt with a low heat capacity, e.g. below 3.1×10^{-3} cal./cm.^{2}/°C. Additionally, heat absorption in the substrate for belt 61 can be eliminated or substantially diminished by coating it with a thin reflecting layer such as aluminum. The transfer surface of belt 61 can be formed from many materials, the preferred materials being silicone rubbers such as General Electric RTV 615 or Dow Corning 3140 and certain fluoroelastomers. A typical belt is comprised of a polyimide substrate of 0.5—5 mils coated with a reflecting layer of aluminum about 300 angstroms thick and a silicone rubber transfer surface 0.1—10 mils thick.

Transparent transfer belts can also be used to increase thermal efficiency and a suitable transparent belt is disclosed by British Patent Specification No. 1,152,067.

The transfer belts should also have certain surface properties so that efficient transfer of toner is possible. The surface should be smooth, have good release properties (e.g., surface free energy below 40 dynes per centimeter), and have the proper hardness (e.g., 3 to 70 durometers on the Shore A scale).

Fusing system 80 also contributes to the overall thermal efficiency of the copier. As mentioned above, a radiant fusing system is chosen because radiant heat tends to selectively heat toner on the surface of belt 61. Additionally, slidable shield 83 allows the machine to consume lower power in a standby condition, but to produce copies immediately upon startup since shield 83 stores heat within the lamp chamber in its closed position.

Thermal efficiency is also built into the paper transport system since paper exiting from the machine acts as a heat sink. Because of this, the paper and belt are kept in contact for significant amounts of time as mentioned above. Besides carrying unwanted heat out of the machine, this elongated contact also removes any heat present in the belt which eliminates heat transfer back to photoconducttive drum 10 at T_1.

Other transfer and fusing systems or modifications can be used in other embodiments of the invention defined in the accompanying claims. For example, transfer at T_1 is illustrated as being achieved by pressure contact between belt 61 and drum 10. Nevertheless, electrostatic transfer can be used, and in some cases might even be an advantage since a thin air space would then be provided to insulate photoconductive drum 10 from any back transfer of heat. Alternatively, in place of the radiant heater 80 other fusing systems utilizing radiant energy emitting means, such as microwave fusing systems, might be provided which would result in the selective transfer of heat to the toner and the other general heat efficiencies mentioned. The final support medium is illustrated as being paper, which is most commonly used, but other final substrate medium could be used in place of the paper.

The copier described herein can be operated in an image preservation mode. That is, multiple copies can be made from one exposure. This mode of operation does further the goals of providing a high speed but compact copier.

WHAT WE CLAIM IS:—

1. An electrophotographic copier comprising:

a. a rotatable drum having a photoconductive, insulating surface thereon;

b. means to apply a uniform electrostatic charge pattern to the surface of said drum;

c. means to expose said uniform electrostatic charge pattern to a light image of an original thereby forming a latent electrostatic image of the original on the surface of said drum;

d. cascade developer means for cascading electroscopic developer over said latent electrostatic image, said cascade developer

means including a member closely positioned to the surface of said photoconductive drum and defining a narrow development zone therebetween, said member having means associated therewith for partially converting the tangential momentum, with respect to the drum, of developer particles passing in use through said zone into radial momentum with respect to the drum;

e. An intermediate transfer belt positioned to remove the developed toner image from the surface of said drum;

f. radiant energy emitting means for heating the toner image on said electrostatic transfer belt; and,

g. means for bringing one or more substrate mediums into contact with heated toner image on said transfer belt whereby said image is transferred and fused to said substrate medium, which means is adapted to maintain contact between said transfer belt and said substrate medium after transfer of the toner image to the substrate medium.

2. Copier according to claim 1 wherein said member of the cascade developer means has a roughened surface facing said drum.

3. Copier according to claim 2 wherein said development plate has protuberances thereon for effecting said momentum conversion.

4. Copier according to any of claims 1 to 3 wherein said member of the cascade developer means is an electrode.

5. Copier according to any of claims 1 to 4 wherein said intermediate transfer belt comprises a silicone, elastomeric transfer belt having a heat capacity of below 3.1×10^{-3} cal./cm.^{2}/°C.

6. Copier according to any of claims 1 to 4 wherein said intermediate transfer belt comprises silicone rubber or fluorelastomers.

7. An electrophotographic copy process employing a copier according to any of claims 1 to 6.

8. Electrophotographic copier substantially as hereindescribed with particular reference to the accompanying drawing.

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1494218 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*